Government of Canada
Environmental Assessment Review

Gouvernement du Canada
Examen des évaluations environnementales

AUG 15 1980

Ottawa, Ontario
K1A 0H3

August, 1980

Dear Sir/Madam:

I am pleased to forward the most recent submission(s) received by the Norman Wells Environmental Assessment Panel. As additional information becomes available, it will be made available to you.

Yours sincerely,

R.L. Greyell
Executive Secretary
Norman Wells Pipeline Project

Rec'd: Aug 15/80
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1980 July 21

Your file Votre référence

Mr. R.L. Greyell
Executive Secretary
Norman Wells Project
Federal Environmental Assessment Review Office
13th Floor, Fontaine Building
Ottawa, Ontario
K1A 0H3

Our file Notre référence
T 8185-21-10

F. E. A. R. O.
AUG 6 1980

Dear Mr. Greyell:

This has reference to your telephone request to Inspector Hamilton, Officer Commanding my Yellowknife Sub-Division, of July 8th and the telephone response from Staff Sergeant J.R.H. Scott of my Planning Section of July 18th. As promised by S/Sgt. Scott, attached is a copy of the draft of questions supplied to Esso Resources Canada Limited and to Interprovincial Pipeline Limited.

As outlined to you by S/Sgt. Scott, the attached draft of questions respecting the development of the Norman Wells oilfield and the construction of a pipeline from Norman Wells, N.W.T. to Zama Lake, Alberta, have been gleaned from all Detachment Commanders and Officers Commanding of Sub-Divisions who will be policing the areas involved. We have received excellent cooperation to date from both I.P.L. and Esso Resources with respect to the policing interests of the R.C.M. Police in the above developments.

We will be meeting again with the representatives of Esso Canada Resources Ltd. and I.P.L. Ltd., when they are prepared to discuss their responses to our draft of questions. It could be that some of our questions and/or their responses may raise ramifications of which I am not aware at this time, therefore full disclosure and discussion may take sometime, possibly a month or two. As explained by S/Sgt. Scott, we may not be fully prepared to discuss all the law-enforcement aspects of the Socio-Economic Impact Assessment (Volume IV of 4) of this Project at the time of your visit to Yellowknife during the last week in August 1980.

...../2

Commanding Officer Commandant divisionnaire

41424

Therefore, the attached draft is being forwarded to you in order that you may advise the panel of the direction the R.C.M.P. interests lie in this Project, as well as advising the Board of the present standing of the negotiations between the companies involved and ourselves.

Thank you very much for your assistance to my Planning Section.

Yours truly,

A.H. Buttler
Chief Superintendent
Commanding Officer

Attach.

"G" Division, R.C.M. Police
Bag 5000, Yellowknife, N.W.T.
X0E 1H0

R.C.M.P. DRAFT OF QUESTIONS FOR INTERPROVINCIAL PIPELINES, LTD. AND ESSO RESOURCES, RESPECTING DEVELOPMENT OF NATURAL RESOURCES AT NORMAN WELLS AND CONSTRUCTION OF THE PIPELINE FROM NORMAN WELLS TO ZAMA LAKE

Camps and Employees

1. What will be the location of each camp along the proposed pipeline route?

2. Which camps will be the main staging camp and which camps will be the smaller or intermediate ones?

3. How many employees will be resident at each camp at any one time?

4. Will work commence at all camps at once, or on different time intervals?

5. What will be the peak months labour activity during the construction years at each camp?

6. How long will work last at each camp?

7. Will there be "hold-over facilities" established for employees travelling to and from the camps? If so, where

8. How long will the employees remain in such "hold-over facilities?

9. Will the camps have aircraft landing strips or helicopter pads? What will be the length of the strips?

10. Will such strips/pads be lighted, or will they be a daylight operation only?

11. Which camps will the answer to question #10 apply to?

12. Will such camps have MOT-approved navigational aids suitable for IFR approaches?

13. Will such camps have JP4 turbo fuel available for purchase by RCMP aircraft?

14. What medical facilities will be available at each camp?

15. Will there be any importation of material or employees that will require customs and/or immigration clearances?

16. Approximately how many NWT residents, or "local hire" personnel, will be employed at each camp?

17. How often and by what means will NWT resident employees be rotated in and out of the camps after regular working shifts to their "place of hire"?

18. Will non-NWT resident employees be hired from, and rotated back to, "outside point of hire"?

19. What is the daily minimum number of hours per shift during the construction period?

20. How and where will employees be paid? (Cash, cheque, etc., at camp, or "point of hire").

21. Will non-NWT residents be hired at these camps if they travel North and present themselves for employment?

22. Will any attempt be made to keep itinerant job-seekers from coming North and hopes of employment? (By media advertising, etc.).

23. Will alcohol be permitted in camps?

24. If the camps are "wet", will the licence premises be controlled by company personnel?

25. Will recreation facilities be provided?

26. Will company policy exist on the importation of liquor, drugs, or firearms, in an employee's belongings?

27. Will employees be allowed or supplied company transportation to spend recreational time in nearby settlements?

28. What will be the company's policy with respect to gambling in the camps?

29. Will there be company policy with respect to behaviour and conduct of the employees in camp?

30 How does the company foresee carrying out their rules and policies with respect to behaviour and conduct?

31. Will there be a policy of termination of employment for infractions of company rules and regulations?

32. What would be the periods of "time off" that employees would have on a regular basis without having to spend such "time off" at his "point of hire"?

33. Will the camps have a "dry canteen" for purchase of sundry personal items?

34. Will identification cards be carried by all members in the event of death by accident, misadventure, etc.? If so, what details would be included?

35. Will there be females employed at the camps? How many and at which camps?

Security of Camps by the Company

1. Will there be controlled access to and from the camps by land, air, and water? By whom and how?

2. Will the camps be fenced and lighted?

3. Will the company employ security personnel at the camps? Will they be trained personnel?

4. What kind of training or experience will the security personnel be required to have?

5. Will the company provide terms of reference for their security personnel to enforce company rules and regulations concerning discipline and conduct of the employees in camps?

6. To which "on site" person will the security personnel be responsible?

7. Should the government decision be made to go ahead, when will actual site preparations begin?

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epfer Coles Nikiforuk Pennell
ociates Ltd. Petroleum Consultants

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1980-07-31
Project: 0-972

F.E.A.R.O.
AUG 6 1980
RECU'D

Federal Environmental
Assessment Review Office
13th floor, Fontaine Bldg.
Hull, Quebec
K1A 0H3

Attention: Mr. R. L. Greyell

Dear Sir

Re: Norman Wells Project

On July 24th, Vic Kloepfer and I met with the following Esso Resources personnel.

S. Mackay - Norman Wells Project
G. Davidson - Reservoir Engineering Supervisor
B. Dawe - Reservoir Engineering Department
J. Bacon - Reservoir Engineering Department

They presented a review of the geological and engineering work which had been performed by Esso, and discussed the reasons for selecting the proposed development methods for the pool. The quality of the presentation and the level of knowledge of the individuals involved indicated that considerable time and effort had gone into the reservoir engineering aspects of the project.

Comments on the three specific areas of concern to your group are as follows:

1) Alternatives to Artificial Islands

As discussed at our meeting of July 21st, there are two possible alternatives to the use of artificial islands, use of a flank (or line drive) waterflood or directional drilling from the mainland and existing islands. Esso has studied both these alternatives.

Flank Water Drive would involve the use of a line of water injectors on the natural islands to "drive oil" across to the mainland. Early model studies indicated that recovery by this method would only total 17 percent of the oil in place, as compared to 15 percent with no secondary recovery scheme, and 50 percent for a pattern waterflood. Time to the 17 percent

recovery was estimated to exceed 200 years. The primary reas for the poor recovery was the low permeability (5-8md average) the reservoir. While the initial studies were based on idealized model, we believe the results are reasonable and that is logical to assume that considerably higher oil recoveries wi result from the use of a pattern waterflood. The low perm ability, the variations in permeability, and natural fracturing the reservoir would all tend to make pattern flooding the mo viable alternative.

Directional drilling from existing land masses would be possib and Esso appears to have spent considerable time and mon evaluating the possibility of horizontal wells such as tho described in Petroleum Society of CIM Paper No. 79-30-10, "Es Resources Horizontal Hole Project at Cold Lake" by G.E. Bezai and F.A. Markiew (copy attached). One horizontal well has be successfully completed at Norman Wells although there seemed to some uncertainty concerning the exact location of the wellbore the reservoir.

Esso indicated that from a purely economic standpoint, this wou be a more desireable alternative than artificial islands, but th they they decided against it on technical grounds. From practical standpoint we would concur with their decision. T horizontal hole concept represents innovative, but essential unproven technology. The potential for drilling problems, we control problems, (particularly the control of injected fluid and reservoir producing problems would, in our opinion, preclu use of the horizontal drilling technique at this time.

Nearly all of the wells proposed by Esso will be directional drilled to some extent. They indicated that the use of the pr posed artificial islands would permit them to contact t reservoir at a maximum angle of 70° from vertical. Each we would be a single completion in the reservoir as opposed to t multiple completions required with horizontal wells. This is t maximum deviation that Esso feels they can afford and reasonably assured of successful well completions and optimizati of production and injection rates. We have not evaluated t economics of well spacing, but Esso indicated that even with twi or half the number of proposed wells, the same number artificial islands would be required.

2) Regarding the effect of repressuring the reservoir on natur oil seeps, Esso indicated the following:

- Oil seeps occur over a large area and not necessarily proximity to the Kee Scarp reservoir.

- Oil of similar analysis to the Kee Scarp oil has been encountered in shallow zones.

- Seismic and other geological data has not indicated any faulting of the Kee Scarp or overlying zones.

- The original reservoir pressure was approximately 690 psi (4758 kPa) at a depth of 1150 feet. A normal static pressure for this depth would be about 600 psi indicating the reservoir to have been overpressured at time of discovery.

- Current plans call for a maximum average reservoir pressure of less than the original pressure and maximum injection pressures of 1200 psi at the injection wells.

- Injection pressures will be maintained below fracture pressures.

If Esso's observations are accurate, it is quite likely that the oil seeps are not directly related to the current Kee Scarp reservoir. If static reservoir pressures are kept below the original pressures and injection pressures are kept at least 100-200 psi below the indicated fracture pressures for the reservoir rock or overlying shales, there should be no effect on existing surface seeps. Reservoir and maximum injection pressures should consider the depth of the reservoir at each well location. The considerable variations in reservoir depth would dictate lower pressures on the updip (mainland) side of the reservoir.

3) Possibility of Uncontrolled Oil Flows

Esso indicated that current reservoir pressures are significantly below original pressures in all areas, that a pressure monitoring program is in effect and that no potential oil producing zones have been encountered between the surface and the Kee Scarp reservoir. They did not feel that the use of deviated or horizontal wells would increase the chance of a blow-out. It would be our feeling that as hole deviation increases beyond the limits of conventional technology, or as the use of new technology increases significantly, there is an increased risk of a blow-out occuring. If conventional drilling, monitoring, and control techniques are utilized, the risk of uncontrolled flows from the Kee Scarp reservoir would appear to be very low. The risks associated with the production and transport of oil from the artificial islands will depend to a large extent on the design of

the islands and underwater pipeline crossings. We do not ha expertise in these particular areas, and cannot effective comment on this subject, other than to note that the technolo of downhole and surface emergency valves is well developed a any flow from a pipeline break could likely be controlled ve quickly.

It should be stressed that our firm has not examined the raw da or model studies on which Esso Resources has based its concl sions. Such a study would cost approximately $50,000 $100,000. From a common sense standpoint, their plans wou appear to be reasonable and to maximize reservoir recovery whi minimizing economic risk. They have examined alternative pla in varying degrees of detail and appear to have chosen the mo logical alternatives. We are not qualified to comment on wheth there are environmental concerns that may dictate anoth development plan, but it is our opinion that further study development alternatives from a reservoir engineering standpoi would not significantly alter Esso's conclusions.

If there are any questions regarding this work, please call your convenience.

Yours very truly

John D. Macgowan

J. D. Macgowan, P.Eng.

JDM/bl

PAPER NO. 79-30-10

THIS IS A PREPRINT — SUBJECT TO CORRECTION

ESSO RESOURCES HORIZONTAL HOLE PROJECT AT COLD LAKE

by
G.E. Bezaire
- Member The Association of Professional Engineers, Geologists and Geophysicists of Alberta
Drilling Engineer - ESSO Resources Ltd.

I.A. Markiw
- Member The Association of Professional Engineers, Geologists and Geophysicists of Alberta.
Drilling Engineer - ESSO Resources Ltd.

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THIS PAPER IS TO BE PRESENTED AT THE 30TH ANNUAL TECHNICAL MEETING OF THE PETROLEUM SOCIETY OF CIM IN BANFF, MAY 8 — 11, 1979. DISCUSSION OF THIS PAPER IS INVITED. SUCH DISCUSSION MAY BE PRESENTED AT THE 30TH ANNUAL MEETING AND WILL BE CONSIDERED FOR PUBLICATION IN CIM JOURNALS IF FILED IN WRITING WITH THE TECHNICAL PROGRAM CHAIRMAN PRIOR TO THE CONCLUSION OF THE MEETING

STRACT

The Alberta Oil Sands comprise the bulk of nada's petroleum reserves. The bitumen in these posits is too viscous to flow naturally and cannot produced by conventional oilfield techniques. here the deposits are close to the surface, mining n be employed to recover the Oil Sands. In many eas, however, the over burden thickness is such at in-situ recovery techniques provide the only ans of recovering bitumen.

This paper describes the drilling details of a ll which will be used in an in-situ recovery pilot Cold Lake. The well, Imp 78 Horizontal Leming 9-6-65-3 was spudded conventionally and then viated so that its final wellbore path was rizontal in the Clearwater formation. Over 1000' pay section was contacted by this well in a zone ich is only 160' thick. Details about the well anning, drilling equipment, drilling fluid, survey rogram, casing and problems encountered are discus-d.

INTRODUCTION

The Alberta Oil Sands are one of the world's largest known reserves of petroleum. The main deposits, Athabasca, Cold Lake, Peace River and Wabasca contain about 900×10^9 barrels, 95% of the petroleum discovered to date in Canada.

The heavy oil in the sands is very viscous and cannot be recovered in its natural state by conventional production methods. The two commercial plants presently in operation surface mine the oil sands and upgrade the bitumen recovered into light oil.

The reserves in the Cold Lake deposit (Figure 1) cannot be recovered by mining techniques because 1000' of over burden overlies the oil bearing sands. Here, in-situ recovery methods provide the only means of extracting the heavy bitumen. There are many recovery pilots in operation in the area and most involve the application of external energy, such as steam, to reduce the viscosity of the heavy

crude and allow production.

To introduce heat into the oil sands, vertical or moderately deviated wells are drilled into the oil bearing formation. Because the wells have limited drainage capabilities, the well spacing is closer than in conventional producing fields and large numbers of wells are required.

A well in which a large section of oil sand can be contacted may provide increases in both production rates and recovery levels. The only means by which such lengths of reservoir can be reached is with a highly deviated well which enters the reservoir at a near horizontal inclination.

Imp 78 Horizontal Leming Ex 9-6-65-3 is such a well. It was spudded conventionally on March 21, 1978 and then deviated so that its final wellbore path was horizontal, 1558' below the surface. This paper discusses the methods and techniques employed to drill this well.

PLANNING

(a) Pre-Program

Esso Resources (formerly Imperial) has operated pilot studies in the Cold Lake area since 1964. Over 100 evaluation wells and 190 pilot related wells have been drilled to date. The initial pilot wells were vertically drilled but more recent wells have been deviated up to 35^{o} from vertical.

Only minor drilling problems have been encountered at Cold Lake. The first 500' of over-burden is unconsolidated glacial drift. This formation enlarges somewhat as the well is drilled but is sufficiently competent to allow angle buildup. Marine shales underlie the drift zone. These shales are more competent than the upper drift zone and stay near gauge during the drilling operation. The oil sands underlying the shale section are a non-cemented mixture of rock fragments and clay minerals. This formation drills very quickly and hole stability is usually good.

Because all previous wells in the area were only moderately deviated, a comprehensive literature search of high angle drilling was undertaken before planning began. Wherever possible, operators, contractors and service companies having experience with this type of drilling were contracted before the well program was prepared. Thus, equipment tools which had worked successfully in other ar were identified.

The initial objectives of the horizontal project were:

- 1000' of pay zone was to be penetrated the Clearwater Formation
- the hole was to be near the bottom of t Clearwater
- accurate knowledge of the bottom hole location was required
- the desired production casing size was 7-5/8"

(b) Drilling Program

In order to accomplish the objectives, the following drilling program was prepared. As wil discussed later, not all these steps were actua followed:

1. Pre-set the conductor pipe.
2. Drill a 12-1/4" hole to kick-off dept of 150'.
3. Run a 7-3/4" Dyna-Drill with a 12-1/4 bit to 630' T.V.D., building angle at 4-1/4°/100'.
4. Run a multishot magnetic survey.
5. Ream the 12-1/4" hole to 17-1/4".
6. Underream the 17-1/4" hole to 21".
7. Run 16" surface casing and cement to surface.
8. Head up and displace casing to oil-muc
9. Drill out the float and shoe with a 14-3/4" bit.
10. Run in with an 8-3/4" bit and build an at 4-1/4°/100' to the Clearwater (approximately 1451' T.V.D.).
11. Run a multishot survey.
12. Ream the 8-3/4" hole to 9-1/2".
13. Ream the 9-1/2" hole to 14-3/4".
14. Run 10-3/4" casing to the shale above Clearwater (approximately 1441' T.V.D. and cement to surface.
15. Run a gyro survey.
16. Drill out with a 9-1/2" bit and make 5 of hole below casing shoe.
17. Drill with a 7-7/8" bit and build angl at 4-1/4°/100' to 1460' T.V.D.
18. Build angle at 1°/100' to 1561' T.V.D.
19. Run a multishot survey.
20. Ream the 7-7/8" hole to 9-1/2".
21. Run a 7-5/8" slotted liner.
22. Install the wellhead and release the

A number of operational considerations inf-
ıced the procedures which were included in the
ve program:

- The kick-off depth was to be as shallow as possible in order to minimize the rate of angle build up.
- A comprehensive directional survey program was needed to ensure the directional objectives were met.
- The optimum hole size for directional drilling was 7-7/8" - 8-1/2", thus requiring a pilot hole, later reamed to a larger size.
- Underreaming the surface hole was necessary because the rig used has a 17-1/2" rotary table. A 21" hole was required to run the 16" surface casing.

In order to increase the chances of successfully
pleting this program, a spare 5-1/2" slotted liner
prepared. If hole stability was such that the
'ling in the horizontal section could not be
tinued, then the 7-5/8" liner would be run.
ling would continue below the 7-5/8" liner and
smaller liner would be run to bottom. Similarily,
the 7-5/8" liner became stuck during the running
ration, it would be possible to drill out the end
the liner, clean out the hole, and run the 5-1/2"
er to bottom.

Organization

Personnel for this operation were selected so
decision making could be concentrated at the
site. Two drilling supervisors and a drilling
neer were on location at all times along with
erienced service company personnel. Because of
large number of people on the lease, an organiza-
chart (Figure 2) was prepared to identify
ponsibilities and communication paths. A chart,
ining when certain variables, such as angle
d-up rate and hole drag were becoming critical,
also prepared. This alerted personnel to
ntial problems and ensured that remedial proced-
could be undertaken without delay.

ATING DATA

Wellbore Path

Forty-two days after spud, well 9-6 was success-
y completed. The final angle at the bottom of
hole was 90.2 from vertical (Figure 3). The
was horizontally displaced 2045', while the
l vertical depth reached was 1558' K.B. In order to accomplish this, it was necessary to drill 2955' of hole.

The main program objective was obtained - 1059' of pay penetrated in the Clearwater formation, a zone which is 160' thick.

(b) Time Analysis

Because of the numerous steps involved in the program, the total time required to drill was longer than would be expected for a normal 3000' well. The progress in depth vs. the days from spud is shown in Figure 4. The time required to complete various operations is listed in Table I.

TABLE I

TIME ANALYSIS

OPERATION	TIME (DAYS)	% OF TOTAL
Drilling	2.9	6.9
Ream Hole to Larger Size	5.3	12.6
Surveys	3.8	9.0
Tripping	2.9	6.9
Run Casing	3.6	8.3
W.O.C., Head-Up, Drill Out	4.3	10.2
Ream to Bottom	3.1	7.4
Miscellaneous Operations and Problems	16.2	38.6

(c) Drilling Rig

The rig selected for well 9-6 is rated to drill to 7500'. A rig this size was used for the following reasons:

- Sufficient pump capacity was required to clean hole sizes up to 21" in diameter.
- Sufficient hoisting capacity was required in the event of severe drag.
- The mud system had to accommodate additional solids control equipment.
- The table had to be sufficiently large to run 16" casing.
- The capability of pulling triples simplified handling of some bottom assemblies.

The rig specifications are listed in Table II.

TABLE II

ESSO RIG 2E SPECIFICATIONS

Drawworks	- 600 h.p.
Mud Pump	- 560 h.p.
Table Size	- 17-1/2"
Mud Tank Volume	- 400 bbls
Mud Solids equipment	- Shale Shaker, Desilter, Centrifuge

(d) Downhole Tools

Two general types of downhole assemblies were used in drilling the well, an angle building assembly and a hole opening assembly. All components were conventional pieces of equipment, locally available.

(i) Angle Building Assembly

Figure 5 shows the angle building assembly. This basic assembly, although varied slightly in different portions of the well, was used to pilot the surface and intermediate hole and to drill the production hole. On the bottom was a mill tooth bit rotated by a Dyna-Drill. This downhole hydraulic motor is powered by pumping mud down the drill pipe. A 6-1/2" Dyna-Drill was used in both the 12-1/4" and the 9-1/2" pilot holes.

Angle building was accomplished using either a bent sub or a bent housing Dyna-Drill. The selection of the proper kick sub was determined by the directional driller according to his progress relative to the angle building target. The three subs used, 1.5°, 2°, and 2.5 provided varying angle build-ups as shown in Figure 6.

Non-magnetic drill collars were run above the Dyna-Drill. Three non-magnetic collars were run to the 10-3/4" casing point and four were run from there to bottom. In highly deviated holes the magnetic interference of drill pipe on the directional survey compass is more pronounced than in vertical holes. The number of collars that were run, adequately removed any interference and allowed high quality surveys.

Heavy weight drill pipe was run immediately behind the monel collars. This pipe provided some weight on bit, but its main purpose was to place the steel drill collars further uphole as the wellbore approached the horizontal. This unconventional arrangement had two advantages, the heavy drill collars were placed in a more vertical section of the hole, providing weight on the bit more effectively, and secondly, the chances of differentially sticking the drill string were minimized because of the reduced diameter of the heavy weight pipe in the highly deviated hole section.

(ii) Hole Opening Assembly

While opening the hole, the drill was rotated conventionally and the reame (Figure 7) effectively followed the pilo The ported bullnose allowed circulation the pilot hole, the non-rotating stabili short and would not bury itself in the s the hole. Because this stabilization wa gauge, it prevented excessive assembly v tion.

(e) Directional Survey

Directional surveys played a critical ro the success of this project. The hole had to drilled in a particular direction, but in add it was imperative that the bottom hole locati known extremely accurately. Therefore, a com sive survey program was carried out.

(i) Equipment

The steering tool was used at all in the pilot holes. This tool consists downhole directional sensing package whi in the non-magnetic drill collars. It i connected by wireline to surface providi constant surface readout of hole directi indicating when direction is unsatisfact This allows immediate corrective action taken if necessary, which is particularl important in the high angle portion of t

Single shot magnetic surveys were every 60' to provide a permanent survey as the hole progressed.

A magnetic multishot survey was ru each casing point to provide a continuou survey record.

A gyroscopic survey was run inside 10-3/4" intermediate casing to provide r magnetic confirmation of the multishot s

(ii) Computation

In addition to accurate data, a qu reliable computation method was necessa telephone link from the drilling locati IBM 370 computer in Edmonton was availa continuous computation of hole trajecto maintained.

(iii) Results

In the final analysis the survey record which best represented the wellbore path was the combination of the gyro survey to intermediate casing point meshed with the multishot magnetic survey from the intermediate casing to total depth.

However, if the directional requirements were less stringent, a reduced survey program would be sufficient to drill the well.

The continuous surface readout appears to be indispensible for operational purposes. Either the multishot or gyro survey appear to be satisfactory as a survey record.

Drilling Fluid

The care with which drilling fluid is selected maintained is a critical part of every drilling ram. In high angle wells, the drilling fluid is more critical since it must minimize torque and as well as clean the hole.

An oil-mud is a preferred fluid in such applications. This mud consists of a continuous oil phase, lly diesel oil, with water emulsified in the oil. tives are used to stabilize the emulsion, oil mud solids and impart viscosity and fluid loss rol to the mud.

Laboratory tests were run to determine the ility of heavy oil sand in the presence of both and water base mud. The tests simulated the r rate which would exist at the wellbore face to the circulating fluid. Although some hole rgement was observed in both cases, hole ility with the oil-mud was superior.

A fresh water-gel mud was used to drill the face hole. Fresh water sands close to surface nibited the use of an oil-mud in this part of well. Mud viscosity of 45 sec/qt was adequate clean the hole during both the 12-1/4" Dyna-Drill and the hole opening to 17-1/2" and 21".

Once the surface casing was installed, the sh water based gel mud was displaced to the oil-. The initial mud weight was 8.0 ppg with a o/100 ft² yield point. Connections were tight oughout the piloting operation because of poor e cleaning. This was due in part to the circulan rate which had to be maintained through the Dyna-Drill, which in turn limited the annular velocity. Conditions improved when the yield point was increased to 18 lb/100 ft². The mud properties at 1828' during pilot hole drilling, at 1937' after reaming the intermediate hole and in the horizontal section are shown in Table III. Overall, the muds used performed very well. No drilling problems were encountered and drag on trips was usually about 10,000 to 15,000 pounds in lower portions of the hole.

Solids control on the rig consisted of a shaker, 12 cone desilter and centrifuge. The shaker and desilter were used during surface hole and the centrifuge was used when the oil based mud was run. This equipment maintained drill solids below 5% by volume.

In order to minimize mud losses and spillage while using the oil-mud, extra equipment was installed on the rig as shown in Figure 8.

TABLE III

OIL-MUD PROPERTIES

	DEPTH 1828' (PILOT HOLE)	DEPTH 1937' (REAMED HOLE)	DEPTH 2830' (DYNA-DRILLED HOLE)
Mud Weight	8.1 ppg	8.5	8.1
Viscosity	65 sec/qt	70	61
PV	23 cp	28	26
YP	19 lb/100 ft²	28 cp	18
Gel Strength	7/8 lb/100 ft²	12/19	7/8
Solids	3%	6	4
Oil	76%	74	75
Water	21%	19	21

(g) Drag And Weight On Bit

As the hole inclination approached higher angles, the frictional drag on the drill string increased and satisfactory weight on bit became more difficult to maintain.

Figure 9 shows the situation at total depth. The different sections of the drill string are plotted against the factors which influence hook load, i.e., depth, inclination angle, and component weight.

The effective weight component is the weight of the section of the drill string multiplied by the cosine of the average inclination angle for that

section; this component of drill string weight provides weight on bit.

The normal weight component is the weight of the section multiplied by the sine of the average inclination angle; this component of the drill string weight creates drag.

At the depth shown in Figure 9, all available weight on bit had been used up and it would have been necessary to add more drill collars uphole in order to continue drilling. This fact makes possible the computation of an average friction co-efficient for the hole.

By dividing the total effective weight on bit by the summation of all normal force components, the friction co-efficient is calculated to be .54. It should be noted that this co-efficient is actually a composite of classical drag, plus a ploughing force on the pipe connections in the open hole. Also, it was achieved with oil based mud in the hole; no doubt it would have been much higher if a water based drilling fluid had been used.

(h) Casing and Cementing

The casing strings run in the well consisted of the conductor pipe, surface casing, intermediate casing and production liner as shown in Figure 3.

The conductor pipe was 24" in diameter and was set before the drilling rig moved onto the lease.

The surface casing string was run through the glacial drift and set at 549' measured depth. The hole angle at this point was 19.5° but no problems were encountered in running the casing. The 16" casing had a yield strength of 55,000 psi and was cemented to surface with Class "G" Oilwell cement.

The 10-3/4" intermediate casing string was set at the top of the Clearwater Formation. Although the hole angle at the bottom of the string reached 70.1°, there were no problems in running the casing to bottom through the oil-mud.

The intermediate string was designed to withstand the elevated temperatures common in wells undergoing thermal stimulation combined with stress due to a deviated wellbore. Stress in constrained casing builds up as temperature is increased in accordance with equation (1).

Equation .....

$$\sigma_c = \alpha E (\Delta T)$$

where σ_c = compressive stress, psi

α = co-efficient of thermal expansion in./in.-°F

E = elastic modules, psi

ΔT = temperature change, °F

Over the temperature range of interest, equa (1) yields a compressive stress of about 200 psi.

If steam is injected down a casing-tubing annulus, the internal pressure, in conjunction wi the compressive stress due to heating, creates biaxial stress. The effect of combining these stresses can be analyzed using Mises yield criter

In addition to the thermal related stress, bending the casing in a deviated wellbore create tensile stress on the outside of the bend and com pressive stress on the inside of the bend. The stress due to bending is given by equation (2).

Equation .....

$$\sigma_b = 4218 (\theta) (D)$$

where σ_b = bending stress, psi

θ = rate of change of angle, °/100'

D = outside diameter, in.

For 10-3/4" casing in a wellbore deviated 5°/100', the stress due to bending is 11,700 psi the outer fibers.

In order to operate under these conditions, casing with buttress joints and a yield strength of 95,000 psi was used. It was designed to unde limited plastic deformation if necessary in acco dance with a procedure outlined by Holliday[1].

The intermediate string was cemented to sur with Oilwell cement + 30% silica flour. This ce mixture retains its strength under high temperat conditions.

As an added precaution, the intermediate st was made up using tongs which measured both the torque and turns applied to the casing, thus all ing identification of proper or improper joint make-up.

The last string run was the 7-5/8" liner. was run to bottom and tied back to the intermedi casing string. This liner was not cemented in p and perforated. Instead, 800' of the liner was

lotted, allowing bitumen production, yet minimizing he amount of sand which could enter the wellbore.

In order to reduce friction and drag while unning the liner, a Hydril Super "EU" connection as selected. This joint has a tapered shoulder on he coupling in comparison to a square shouldered PI connection. No centralizers were used on the iner.

The shoe on the liner was brass and could be rilled out if necessary. Thus, the hole could have een conditioned and the spare 5-1/2" liner could ave been run if the larger liner became stuck uring the running operation. A 2-7/8" stinger was ied into the shoe so that fluid could be circulated o the end of the liner if fill was encountered.

The 7-5/8" liner went to bottom without problem. t was not necessary to circulate through the tinger as no fill was encountered.

i) Problems

A number of problems were encountered in the urface hole. The corrective action proved success- ull in each case and after surface casing was set, rogress was relatively trouble free.

The most troublesome problem occurred in en- arging the 12-1/4" pilot surface hole. The original lan called for a 30' long bullnose to guide the ole opener in the pilot hole. This tended to bury tself in the soft formation and start drilling a ew hole. The surface pilot hole was drilled three imes before it was discovered that a short non- otating stabilizer ahead of the hole opener was est able to follow the pilot hole. Although 7 days ad been planned to drill surface hole, run casing nd head up, it took 14 days. This assembly was sed again in opening the intermediate hole and it erformed very well.

Initially the wireline connecting the steering ool to surface proved troublesome. The line ontinually frayed at the rope socket on the down- ole instrument requiring repairs or fishing. It as determined that vibration was causing the damage. latching device for the downhole instrument was nstalled and tension was held on the wireline while rilling. The problem disappeared for the remainder f the hole.

At surface casing point a multishot survey was was planned. The Dyna-Drill was pulled and a slick string was run in. Severe bridging was encountered on the trip and finally the Dyna-Drill and bent sub were run and the multishot survey taken with these tools in the hole. Succeeding multishot surveys were run in the same manner without problem.

More interesting than the problems encountered are those that had been anticipated but which proved to be minor.

One question was whether weight on bit could be maintained against frictional forces in the horizontal section of the hole. The heavy weight pipe and drill collars uphole, combined with the low co-efficient of friction provided by the oil base mud allowed sufficient bit weight to be maintained. In fact, more horizontal hole could have been drilled if it had been required.

A second question was whether the angle build up rate of 4-1/4°/100' could be maintained. The surface hole was piloted with 12-1/4" bits and inclination angle was built successfully. The intermediate pilot hole size was planned to be 8-3/4" to provide a good chance for angle build up, but the program was changed after our success with 12-1/4" pilot hole. Pilot hole of 9-1/2" was drilled (normally more difficult) and no serious problems were encountered. This made it possible to open the hole from 9-1/2" to 14-3/4" in one step compared to the two step procedure in the drilling program.

A very serious concern was whether the large casing, particularly the 10-3/4", would go down the crooked hole and contingency designs were prepared at great expense. All casing strings went in very smoothly.

(j) Cost

The drilling cost of the horizontal well was about 8 times the cost of a typical producing well. The pay section contacted was about 7 times greater than that reached by a typical well.

To some extent, the cost of this well was inflated by the experimental nature of the project and by the contingencies built into the program. Significant savings could be realized in future wells if casing sizes were reduced to 13-3/8", 9-5/8", and 5-1/2". It would also be possible in future wells to drill more than 1000' of near horizontal hole and the incremental cost of this drilling would be

reasonable since much of the investment is in the uphole portion of the well.

SUMMARY

The successful completion of Leming Ex 9-6-65-3 broadens the horizons of the drilling industry. To our knowledge, it is the only well of this nature drilled by the petroleum industry in the Western world. The well was drilled using conventional technology and, in most cases, local services. The credit for drilling this well lies not only with the engineering and supervisory personnel involved with the project, but also with the high calibre of personnel and equipment supplied by the respective service companies. Although designed for the heavy oil sands, a horizontal well may have applications in conventional reservoirs. A well having a long horizontal path in a producing zone could improve reservoir recovery as well as the economics of infill drilling. In addition, fields inaccessible because of surface constraints can now be tapped. Thus, more wells of this type may well be drilled in the future.

ACKNOWLEDGEMENTS

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COLD LAKE - OIL SANDS DEPOSITS

FIGURE 1

COLD LAKE
HORIZONTAL WELL ORGANIZATION CHART

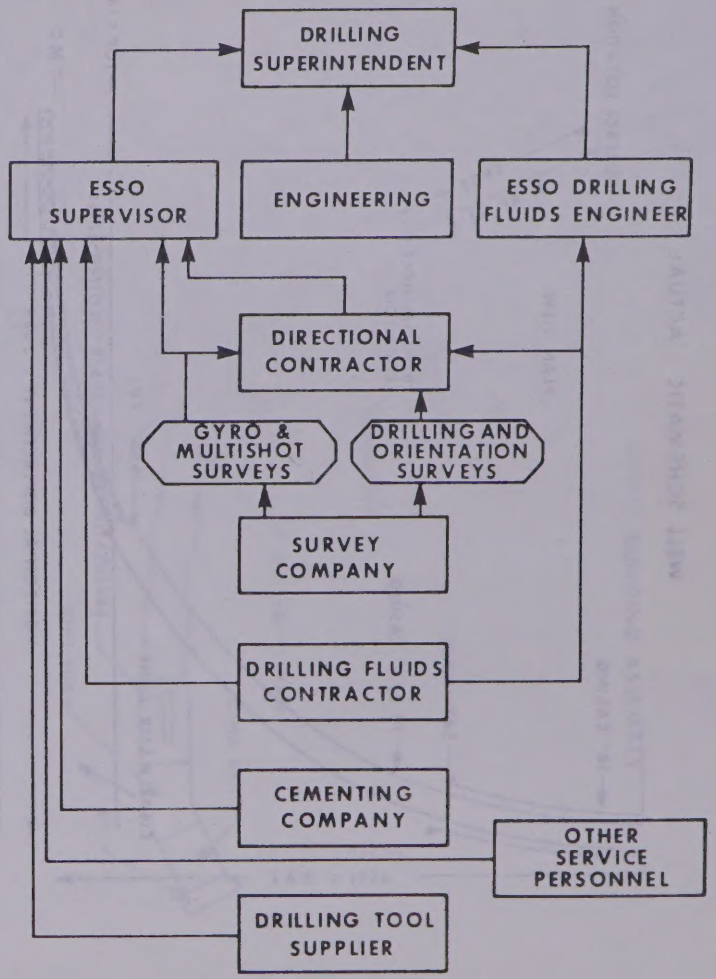


FIGURE 2

WELL SCHEMATIC - ACTUAL

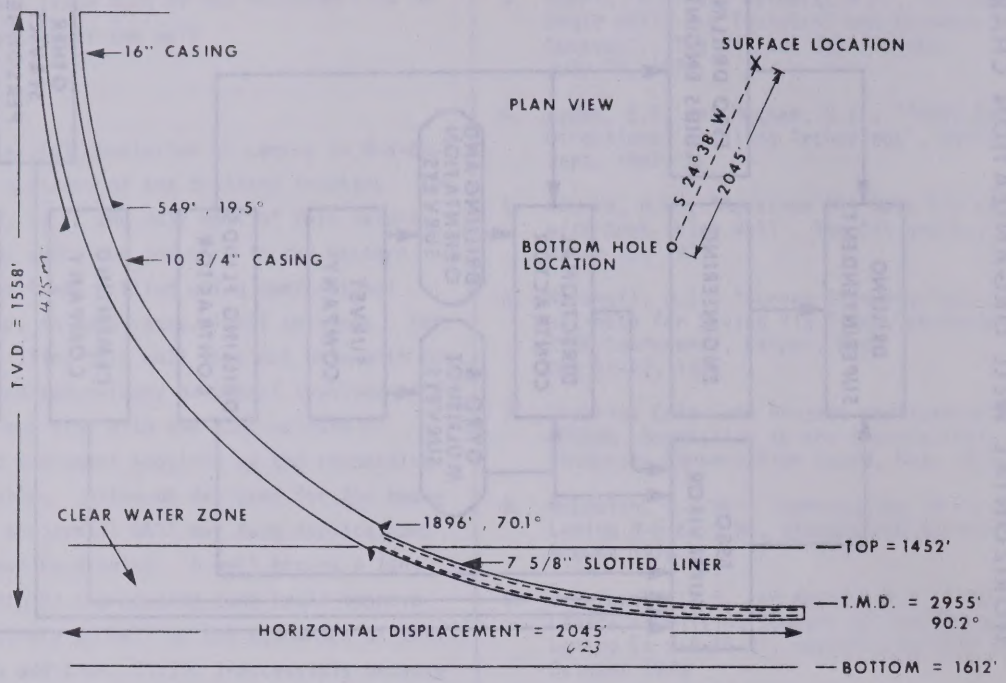


FIGURE 3

DEPTH VS DAYS

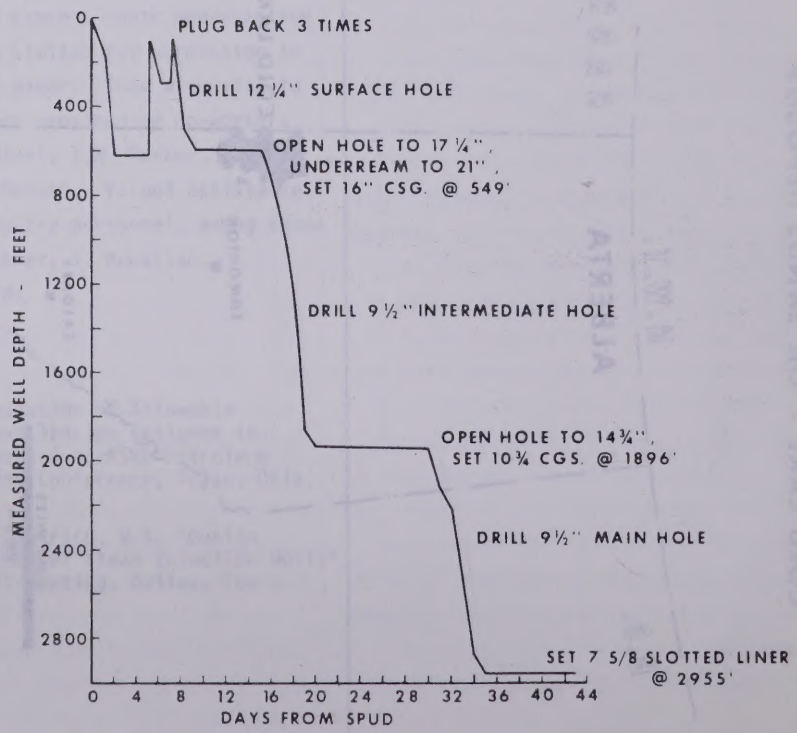

PLUG BACK 3 TIMES
DRILL 12 ¼" SURFACE HOLE
OPEN HOLE TO 17 ¼", UNDERREAM TO 21", SET 16" CSG. @ 549'
DRILL 9 ½" INTERMEDIATE HOLE
OPEN HOLE TO 14¾", SET 10¾ CGS. @ 1896'
DRILL 9½" MAIN HOLE
SET 7 5/8 SLOTTED LINER @ 2955'
MEASURED WELL DEPTH - FEET
0
400
800
1200
1600
2000
2400
2800
0 4 8 12 16 20 24 28 32 36 40 44
DAYS FROM SPUD

FIGURE 4

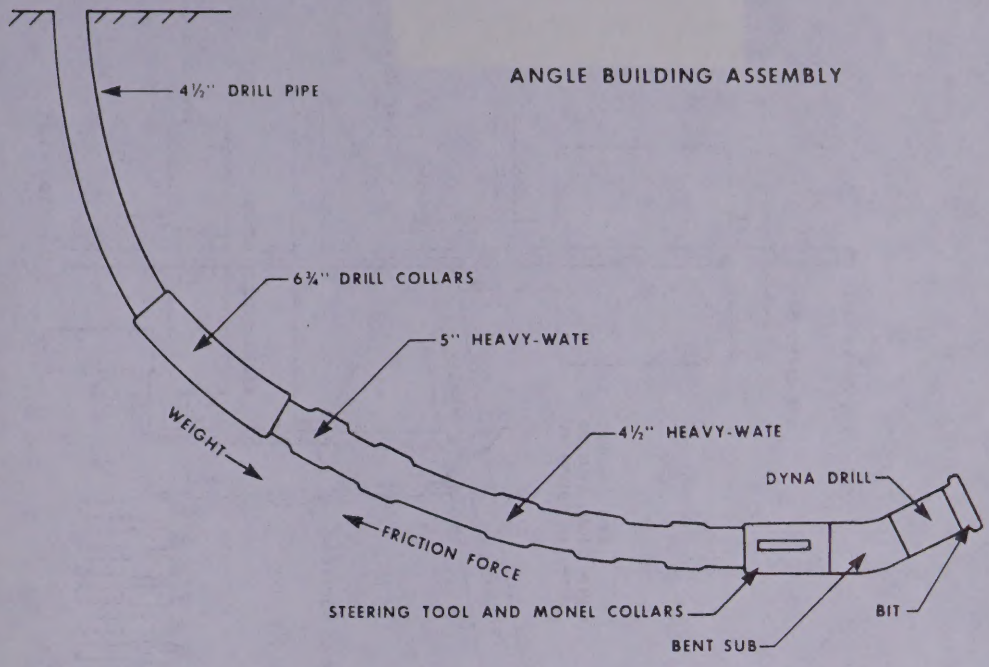


FIGURE 5

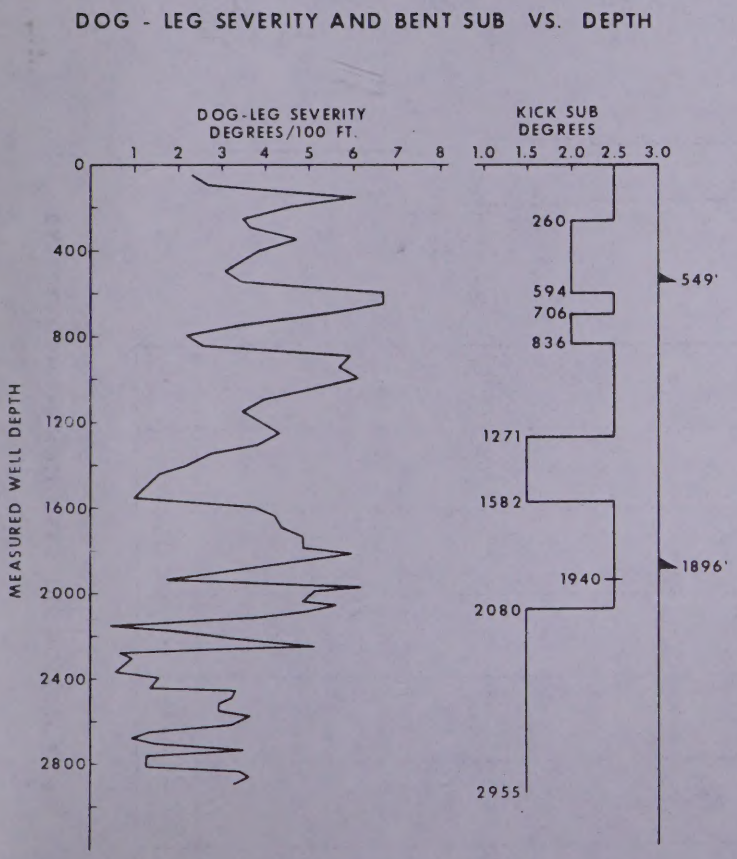


FIGURE 6

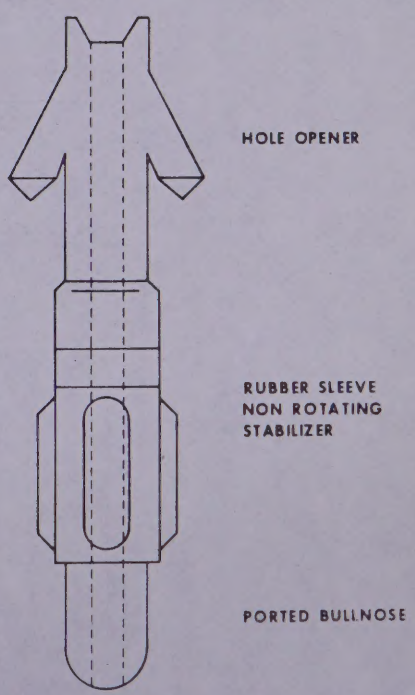


FIGURE 7

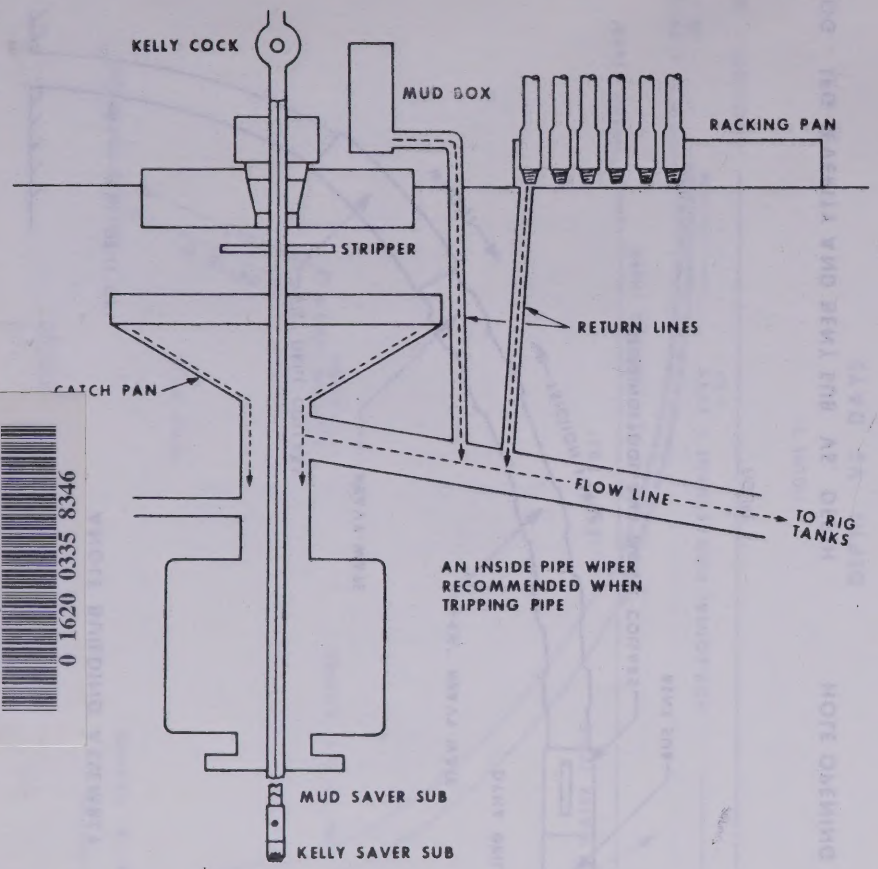
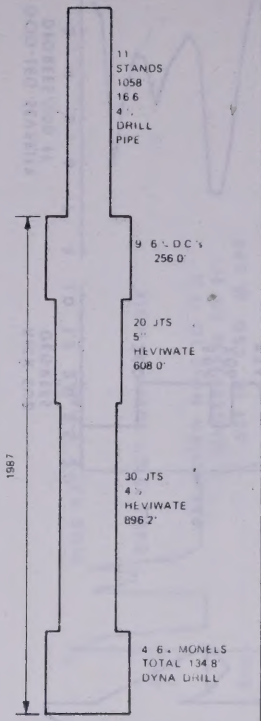


FIGURE 8

CALCULATION OF HOLE DRAG OFF BOTTOM AT TD.


11 STANDS 1058 16.6 4" DRILL PIPE
9 6" D.C.'s 256.0'
20 JTS 5" HEVIWATE 608.0'
30 JTS 4½" HEVIWATE 896.2'
4 6" MONELS TOTAL 134.8' DYNA DRILL
1967

MEASURED DEPTH IN FEET	TRUE VERTICAL DEPTH	INCLINATION ANGLE	WT/FT	AIR WT	EFFECTIVE WEIGHT COMP EW	NORMAL WEIGHT COMP NW
0	0	0				
			18	19,044	17,657	7,134
1059.3	968	44°				
			101	25,856	16,963	19,514
1315.5	1135	54°				
			49	29,792	13,641	26,486
1923.9	1426	71.5°				
			41	36,744	6,786	36,202
2820.1	1548	88.8°				
			83	11,188	97	11,188
2955	1558	90.2°				
				TOTAL	54,644	100,524

AT THIS POINT ESSENTIALLY ALL THE AVAILABLE WT HAD BEEN USED TO GET TO FINAL TOTAL DEPTH

$\mu = \frac{54,644}{100,526} = .54$

FIGURE 9

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